CLAIMS

WE CLAIM:

1. A method for modifying a surface of a microelectromechanical device, the method comprising:

loading the microelectromechanical device into a chamber;

preparing a cleaning agent comprising ozone gas and a co-agent that comprises oxygen-containing molecules; and

introducing the prepared cleaning agent into the chamber, for cleaning the surface of the microelectromechanical device in the chamber.

2. The method of claim 1, wherein the step of preparing the cleaning agent further comprises:

mixing ozone gas with the oxygen-containing co-agent that is water vapor.

3. The method of claim 1, wherein the step of preparing the cleaning agent further comprises:

mixing ozone gas with the oxygen-containing co-agent that is hydrogen peroxide vapor.

4. The method of claim 1, wherein the step of preparing the cleaning agent further comprises:

mixing ozone gas with the oxygen-containing co-agent that is acetic acid vapor.

5. The method of claim 1, wherein the step of preparing the cleaning agent further comprises:

mixing ozone gas with one or more oxygen-containing co-agents selected from a group comprising water vapor, hydrogen peroxide vapor and acetic acid vapor.

6. The method of claim 1, wherein the temperature of the chamber is between 40 °C and 400 °C.

7. The method of claim 1, wherein the temperature of the chamber is between 100 °C and 200 °C.

8. The method of claim 1, wherein the pressure inside the chamber is between 1 Torr and 5000 Torr.

9. The method of claim 1, further comprising:

preparing a coating agent; and

introducing the coating agent into the chamber for coating the surface of the microelectromechanical device.

10. The method of claim 4, further comprising:

pumping out the chamber before introducing the coating agent into the chamber.

11. The method of claim 4, wherein the step of preparing the coating agent further comprises:

preparing the coating agent such that after introducing the agent into the chamber, the agent forms a coating layer that is chemically bonded to the surface of the microelectromechanical device.

12. The method of claim 4, wherein the step of preparing the coating agent further comprises:

preparing the coating agent such that after introducing the agent into the chamber, the agent forms a coating layer that is physically adsorbed on the surface of the microelectromechanical device.

13. The method of claim 4, wherein the step of preparing the coating agent further comprises:

preparing the coating agent that comprises a first and second coating components such that after introducing the coating agent into the chamber, the first component of the coating agent forms a coating layer that is chemically bonded to the surface of the microelectromechanical device, and the second component of the coating agent forms another layer that is not chemically bonded to the surface of the microelectromechanical device.

14. The method of claim 1, wherein the step of introducing the cleaning agent into the chamber further comprises:

a) introducing a first component of the cleaning agent into the chamber such that the pressure inside the chamber is at a first pressure value; and

b) introducing a second component of the cleaning agent into the chamber such that the pressure inside the chamber is at a second pressure value that is higher than the first pressure value.

15. The method of claim 8, wherein the first pressure is from 1 Torr to 700 Torr.

16. The method of claim 8, wherein the second pressure is from 10 Torr to 5000 Torr.

17. The method of claim 8, further comprising:

lowering the pressure inside the chamber to a pressure less than the first pressure value; and

repeating the steps a) and b).

18. The method of claim 8, wherein the first component of the cleaning agent comprises ozone gas and water vapor.

19. The method of claim 8, wherein the second component of the cleaning agent comprises ozone gas in the absence of water.

20. The method of claim 4, wherein the step of introducing the coating agent into the chamber further comprises:

a) introducing a first component of the coating agent into the chamber such that the pressure inside the chamber is at a first pressure value; and

b) introducing a second component of the coating agent into the chamber such that the pressure inside the chamber is at a second pressure value that is higher than the first pressure value.

21. The method of claim 12, further comprising:

pumping out the chamber before introducing the first or the second component of the coating agent into the chamber.

22. The method of claim 12, further comprising:

lowering the pressure inside the chamber to a value less than the first pressure value; and

repeating steps a) and b).

23. The method of claim 4, wherein the coating agent comprises an organosilane.

24. The method of claim 4, wherein the coating agent is an organochlorosilane.

25. The method of claim 4, wherein the coating agent is a halogen-substituted organochlorosilane.

26. The method of claim 4, wherein the coating agent comprises perfluoropolyether.

27. The method of claim 4, wherein the coating agent is selected from a group comprising: a carboxylic acid material having the formula $CF_3(CF_2)_a(CH_2)_bCOOH$, wherein a is greater than or equal to 0, and b is greater than or equal to 0; a fluorocarbon material having the formula $C_nH_mF_{(2n+2-m)}$, wherein n is greater than or equal to 1, and m is greater than or equal to 0 and less than (2n+2); a fluorocarbon amine material having the formula $N(C_nH_mF_{(2n+1-m)})_3$ wherein n is greater than or equal to 1 and m is greater. than or equal to 0 and less than (2n+1); a fluorocarbon ether material having the formula $O(C_nH_mF_{(2n+1-m)})_2$ wherein n is greater than or equal to 1 and m is greater than or equal to 0 and less than (2n+1).

28. The method of claim 4, wherein the temperature is from 60°C to 300°C.

29. The method of claim 4, wherein the temperature is from 100°C to 200°C.

30. The method of claim 4, wherein the pressure is from 1 Torr to 760 Torr.

31. A method for modifying a surface of a microelectromechanical device that is assembled within an assembly, the method comprising:

loading the assembly into a chamber;

preparing a gaseous modification agent; and

introducing the gaseous modification agent into the chamber such that the cleaning agent is delivered through a micro-opening of the assembly to the surface of the microelectromechanical device for modifying the surfaces of the microelectromechanical device, wherein the micro-opening has a characteristic dimension around 10 micrometers or less.

32. The method of claim 31, wherein the gaseous modification agent comprises a cleaning agent that cleans the surface after being introduced onto the surface of the microelectromechanical device.

33. The method of claim 32, wherein the cleaning agent comprises ozone gas.

34. The method of claim 33, wherein the cleaning agent comprises an oxygen-containing co-agent.

35. The method of claim 34, wherein the co-agent comprises vapor water.

36. The method of claim 32, further comprising:

introducing a coating agent into the chamber such that the coating agent is delivered through the micro-opening to the surface for coating the surface of the microelectromechanical device.

37. The method of claim 36, wherein the coating agent forms a layer that is chemically bonded to the surface of the microelectromechanical device.

38. The method of claim 36, wherein the coating agent forms a layer that is physically adsorbed on the surface of the microelectromechanical device.

39. The method of claim 36, wherein the coating agent comprises a first component and a second component, wherein the first component forms a layer that is chemically bonded to the surface of the microelectromechanical device, and the second component of forms another layer that is not chemically bonded to the surface of the microelectromechanical device.

40. The method of claim 31, wherein the modification agent comprises a coating agent that forms a layer, said layer being chemically bonded to the surface of the microelectromechanical device.

41. The method of claim 31, wherein the modification agent comprises a coating agent that forms a layer, said layer being physically adsorbed to the surface of the microelectromechanical device.

42. The method of claim 31, wherein the modification agent comprises a coating agent that further comprises a first component and a second component, said first component forming a layer that is chemically bonded to the surface, and said second component forming another layer that is not chemically bonded to the surface.

43. The method of claim 31, wherein the step of introducing the gaseous modification agent into the chamber further comprises:

a) introducing a first component of the modification agent into the chamber such that the pressure inside the chamber is at a first pressure value; and

b) introducing a second component of the modification agent into the chamber such that the pressure inside the chamber is at a second pressure value that is higher then the first pressure value.

44. The method of claim 43, further comprising:

lowering the pressure inside the chamber to the first pressure or lower; and

repeating the steps a) and b).

45. A method for modifying a surface of a microelectromechanical device, the method comprising:

assembling the microelectromechanical device into an assembly that comprises at least two substrates, one of which is opaque to ultra-violet light;

loading the assembly into a chamber;

preparing a gaseous modification agent; and

introducing the gaseous modification agent into the chamber for modifying the surface of the microelectromechanical device.

46. The method of claim 45, wherein the step of introducing the gaseous modification agent into the chamber further comprises:

introducing the agent onto the surface through a micro-opening of the assembly, wherein the micro-opening has a characteristic dimension around 10 micrometers or less.

47. The method of claim 45, further comprising:

a) introducing a first component of the agent into the chamber such that the pressure inside the chamber is at a first pressure value; and

b) introducing a second component of the agent into the chamber such that the pressure inside the chamber is at a second pressure value that is higher than the first pressure value.

48. The method of claim 47, further comprising:

lowering the pressure inside the chamber to a pressure that is equal to or lower than the first pressure value; and

repeating the steps a) and b).

49. The method of claim 45, wherein the modification agent is a cleaning agent for cleaning the surface of the microelectromechanical device.

50. The method of claim 49, wherein the cleaning agent comprises ozone gas and vapor water.

51. The method of claim 49, wherein the cleaning agent comprises ozone gas in the absence of water.

52. The method of claim 45, wherein the modification agent comprises a coating agent for coating the surface of the microelectromechanical device.

53. The method of claim 52, wherein the coating agent forms a layer that is chemically bonded to the surface of the microelectromechanical device.

54. The method of claim 52, wherein the coating agent forms a layer that is physically adsorbed to the surface of the microelectromechanical device.

55. The method of claim 52, wherein the coating agent comprises a first and second component, said first component being chemically bonded to the surface of the microelectromechanical device, and said second component being not chemically bonded to the surface of the microelectromechanical device.

56. A method for modifying a surface of a microelectromechanical device in an assembly, the method comprising:

loading the assembly into a chamber; and

introducing a gaseous modification agent into the chamber such that the agent is delivered through an opening of the assembly to the surface of the microelectromechanical device, further comprising:

a) introducing a first component of the agent into the chamber at a first pressure; and

b) introducing a second component of the agent into the chamber at a second pressure that is higher than the first pressure.

57. The method of claim 56, further comprising:

pumping out the chamber such that the pressure inside the chamber is equal to or less than the first pressure; and

repeating the steps a) and b).

58. The method of claim 56, wherein the modification agent comprises a gaseous cleaning agent for cleaning the surface.

59. The method of claim 58, wherein the first component of the cleaning agent comprises vapor water and ozone gas.

60. The method of claim 58, wherein the second component of the cleaning agent comprises ozone gas in the absence of vapor water.

61. The method of claim 56, wherein the modification agent comprises a coating agent for coating the surface.

62. The method of claim 61, wherein the coating agent forms a layer that is chemically bonded to the surface of the microelectromechanical device.

63. The method of claim 61, wherein the coating agent forms a layer that is physically adsorbed to the surface of the microelectromechanical device.

64. The method of claim 61, wherein the coating agent comprises first and second component, said first component forming a layer that is chemically bonded to the surface, and said second component forming a layer that is not chemically bonded to the surface.

65. A method for processing a surface of a microelectromechanical device during a packaging process for the microelectromechanical device, the method comprising:

assembling the microelectromechanical device into an assembly;

attaching the assembly to a packaging substrate;

loading the package substrate attached with the assembly into a chamber;

preparing a cleaning agent comprising ozone gas and an oxygen containing co-agent;

introducing the prepared cleaning agent into the chamber for cleaning the surface of the microelectromechanical device in the chamber; and

sealing the microelectromechanical device between the package substrate and a cover lid by bonding the cover lid to the substrate.

66. The method of claim 65, wherein the co-agent is vapor water.

67. The method of claim 65, wherein the step of introducing the cleaning agent into the chamber further comprises:

a) introducing a first component of the cleaning agent into the chamber at a first pressure; and

b) introducing a second component of the cleaning agent into the chamber at a second pressure that is higher than the first pressure.

68. The method of claim 67, further comprising:

lowering the pressure of the chamber to a pressure value that is equal to or lower than the first pressure; and

repeating the steps a) and b).

69. The method of claim 67, wherein the first component comprises ozone gas and vapor water; and wherein the second component comprises ozone gas without vapor water.

70. The method of claim 65, further comprising:

pumping out the chamber; and

filling the chamber with a gas before sealing the chamber.

71. A method for processing a surface of a microelectromechanical device during a packaging process for the microelectromechanical device, the method comprising:

assembling the microelectromechanical device into an assembly;

attaching the assembly to a packaging substrate;

loading the package substrate attached with the assembly into a chamber;

preparing a gaseous modification agent; and

introducing the gaseous modification agent into the chamber such that the cleaning agent is delivered through an micro-opening of the assembly to the surface of the microelectromechanical device for modifying the surfaces of the microelectromechanical device, wherein the micro-opening has a characteristic dimension around 10 micrometers or less; and

sealing the microelectromechanical device between the package substrate and a cover lid by bonding the cover lid to the substrate.

72. The method of claim 71, wherein the step of preparing the gaseous modification agent further comprises:

preparing a cleaning agent and comprising ozone gas and a co-agent that comprises oxygen-containing molecules.

73. The method of claim 72, wherein the step of introducing the gaseous modification agent into the chamber further comprises:

introducing the prepared cleaning agent into the chamber for cleaning the surface of the microelectromechanical device.

74. The method of claim 73, wherein the step of preparing the gaseous modification agent further comprises:

preparing a coating agent that is able to form a coating layer chemically bonded to the surface of the microelectromechanical device.

75. The method of claim 73, wherein the step of preparing the gaseous modification agent further comprises:

preparing a coating agent that is able to form a coating layer physically adsorbed on the surface of the microelectromechanical device.

76. The method of claim 73, wherein the step of preparing the gaseous modification agent further comprises:

preparing a coating agent comprising a first and second components, wherein the first component is able to form a coating layer chemically bonded to the surface of the microelectromechanical device, and the second component is able to form a coating layer physically adsorbed to the surface of the microelectromechanical device.

77. A method for cleaning a surface of a microelectromechanical device, the method comprising:

loading the microelectromechanical device into a chamber; and

cleaning the surfaces of the microelectromechanical device in the chamber using a cleaning agent that comprises ozone gas.

78. The method of claim 77, wherein the microelectromechanical device is within an assembly that comprises a substrate that is opaque to ultra-violet light.

79. The method of claim 77, wherein the cleaning agent further comprises: water vapor.

80. The method of claim 77, wherein the cleaning agent further comprises a chemical species that is selected from a group comprising: hydrogen peroxide vapor and acetic acid vapor.

81. A method for processing a surface of a microelectromechanical device during a packaging process for the microelectromechanical device, the method comprising:

assembling the microelectromechanical device into an assembly that comprises at least two substrates, one of which is opaque to ultra-violet light;

attaching the assembly to a packaging substrate;

loading the package substrate attached with the assembly into a chamber;

preparing a gaseous modification agent; and

introducing the gaseous modification agent into the chamber for modifying the surface of the microelectromechanical device.

82. A system for modifying a microelectromechanical device, the system comprising:

a cleaning agent chamber containing ozone gas;

a co-agent source containing an oxygen containing co-agent;

a coating source containing a coating agent; and

a chamber that is connected to the cleaning source, the co-agent source and the coating source.

83. The system of claim 82, wherein the co-agent source contains water vapor.